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Fault Analysis of Double Line Transmission System with STATCOM Controller Using Neuro-Wavelet Based Technique

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ABSTRACT

The STATCOM (Synchronous Static Compensator) based on voltage source converter (VSC) is used for voltage regulation in transmission and distribution systems. The STATCOM can rapidly supply dynamic VARs required during system faults for voltage support. The apparent impedance is influenced by the reactive power injected or absorbed by the STATCOM, which will result in the under reaching or over reaching of distance relay. This paper presents simulation results of the application of distance relays for the protection of transmission systems employing flexible alternating current transmission controllers such as STATCOM. The complete digital simulation of the Static synchronous Compensator within a transmission system is performed in the MATLAB/Simulink environment using the Power System Block set (PSB). This paper presents an efficient method based on wavelet transforms, fault detection, classification and location using ANN technique which is almost independent of fault impedance, fault distance and fault inception angle of transmission line fault currents with FACTS controllers.

Keywords: *Distance relay, Flexible alternating current transmission controllers, STATCOM, 48-pulse Voltage Source Converter, power system protection.*

1. INTRODUCTION

The performance of a power system is effected by faults on transmission lines, which results in interruption of power flow. The quick detection of faults and accurate estimation of fault location helps in faster maintenance and restoration of supply resulting in improved economy and reliability of the power supply. Wavelet Transform (WT) is an effective tool in analyzing transient voltage and current signals associated with faults both in frequency and time domain. Chul-Hwan Kim, et al [1] have used Wavelet Transforms to detect the high impedance arcing faults. Joe-Air Jiang, et al [2] have used Haar Wavelet to detect dc component for identifying the faulty phases. The distance protection schemes using WT based phasor estimation are reported in [3] & [4].

The application of power electronics in new configurations known as FACTS (Flexible AC Transmission Systems) offers the possibility of meeting such demands. FACTS devices are routinely employed in order to enhance the power transfer capability of the otherwise under-utilized parts of the interconnected network. The Static Synchronous Compensator (STATCOM) using GTOs (Gate-Turn-off Thyristors) is a principle state-of the-art FACTS equipment and is now a commercially available additional tool for use by system planners and designers [5, 6] for shunt reactive power compensation in transmission and distribution systems.

The simulation results show the impact of STATCOM on the distance relay. When the STATCOM is operating, the apparent impedance is influenced by the reactive power injected or absorbed by the STATCOM, which will result in the under reaching or over reaching of distance relay discussed in [7]. Furthermore, in the case of the phase-to-phase fault, there is a tendency for the distance relay earth fault element to pick up an external fault [8].

Due to fast developing communication techniques, it is possible to develop communication-aided high-speed digital protection scheme, which suits the EHV transmission. Better performance can be achieved using two terminal synchronized sampling of signals. Global Position System (GPS) based algorithms with better performance and accuracy have been proposed in [9] & [10]. There is always a need to develop innovative methods for transmission line protection. In this paper, Wavelet Multi Resolution Analysis is used for detection, classification and location of faults on transmission lines. Detail D1 coefficients of current signals at both the ends are used to detect and classify the type of fault.

2. WAVELET ANALYSIS

Wavelet Transform (WT) is an efficient means of analyzing transient currents and voltages. Unlike DFT, WT not only analyzes the signal in frequency bands but also provides non-uniform division of frequency domain, i.e. WT uses short window at high frequencies and long window at low frequencies. This helps to analyze the signal in both frequency and time domains effectively. A set of basic functions called Wavelets, are used to decompose the signal in various frequency bands, which are obtained from a mother wavelet by dilation and translation. Hence the amplitude and incidence of each frequency can be found precisely. Wavelet Transform is defined as a sequence of a function {h(n)}(low pass filter) and {g(n)}(high pass filter). The scaling function $\varphi(t)$ and wavelet $\psi(t)$ are defined by the following equations $\varphi(t) = \sqrt{2}\sum h(n)\,\varphi(2t-n)$, $\psi(t) = \sqrt{2}\sum g(n)\,\varphi(2t-n)$ Where $g(n) = (-1)^n\, h(1-n)$ A sequence of {h(n)} defines a Wavelet Transform.

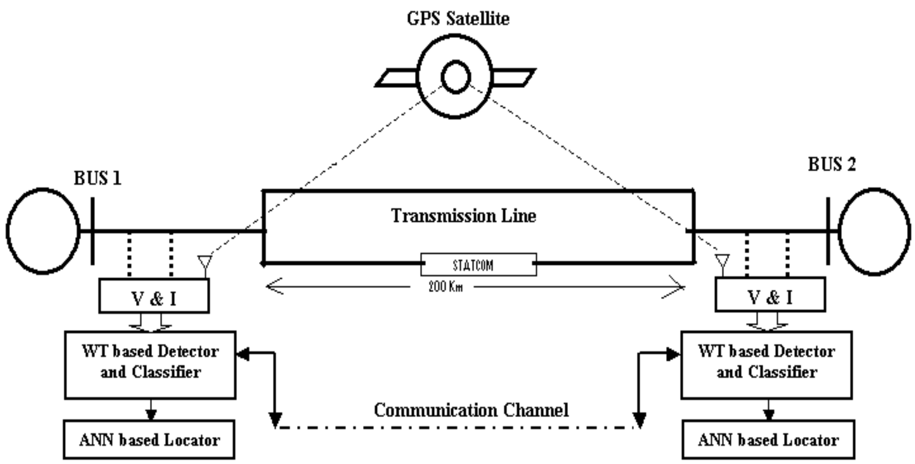


Fig. 1: Power System Physical Model of FACTS Device.

There are many types of wavelets such as Haar, Daubachies, Symlet etc. The selection of mother wavelet is based on the type of application. In the following section a novel method of detection and classification of fault using Multi Resolution Analysis of the transient currents associated with the fault is discussed.

The three phase currents of local terminal are analyzed with Bior.1.5 mother wavelet to obtain the detail coefficients ($D1_L$) over a moving window of half cycle length. These $D1_L$ coefficients are then transmitted to the remote end. The detail coefficients received from the remote bus ($D1_R$) are added to the local detail coefficients ($D1_L$) to obtain effective D1 coefficients ($D1_E$). The Fault Index (**I_{f1}**) of each phase is then calculated as $I_{f1} = \boldsymbol{\Sigma} |D1_E|$.

3. DETECTION AND CLASSIFICATION OF FAULTS

Figure-1 shows the single line diagram of the system considered along with the various blocks of the proposed scheme. Two 200-km parallel 500kV transmission lines terminated in two 9000-MVA short-circuit levels (SCLs) sources and the angle difference 40^0 with 60HZ. The 100MVA and FACTS controller is installed in the middle of the second transmission line. The synchronized sampling of three phase currents and voltages at both the ends is carried out with the help of a GPS satellite. The detail D1 coefficients used for detection and classification of the type of fault are transmitted through the fiber-optic communication channel to the remote end.

The types of three phase faults considered in the analysis are L-G, L-L-G, L-L, L-L-L faults. The simulations show that fault inception angle has a considerable effect on the phase current samples and therefore also on the wavelet transform output of post-fault signals. As the waves are periodic, it is sufficient to study the effect of inception angle in the range of 0^0 to 180^0. The complete flow chart for the classification is as shown in Figure 2.

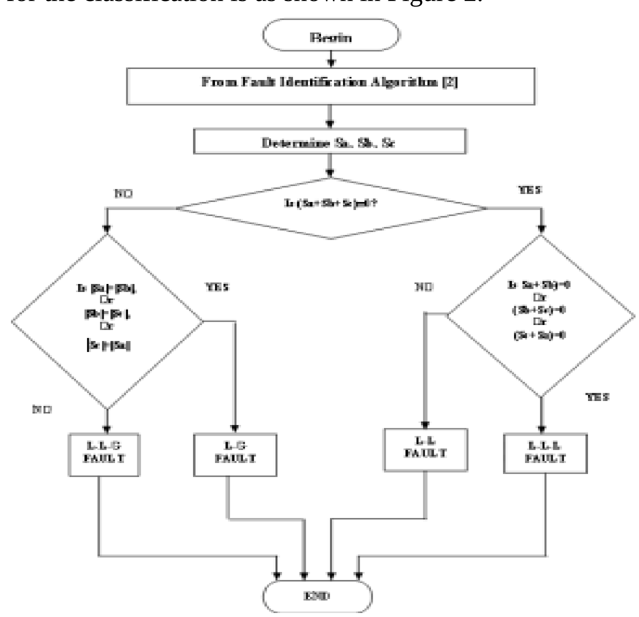
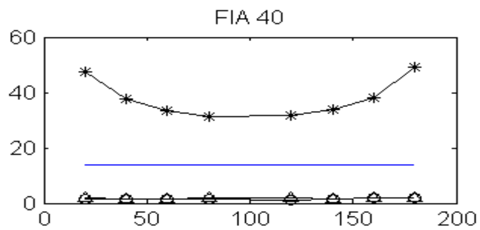


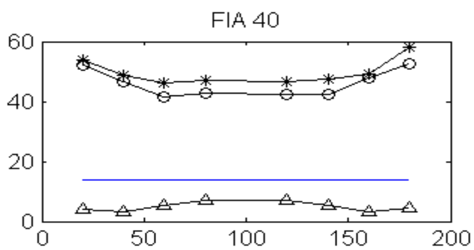
Fig 2. Flow chart for the fault classification and Detection

Subsequent to detection and classification of fault, estimation of fault location is carried out using ANNs [11][12]. For this purpose the three phase voltages and currents of the local terminal are decomposed with Bior 4.4 mother wavelet over a half cycle window are obtained. This is done concurrently with the decomposition D1 used for fault detection and classification to speed up estimation of fault location. In case the fault is detected, the A3 decompositions are obtained for another half cycle.

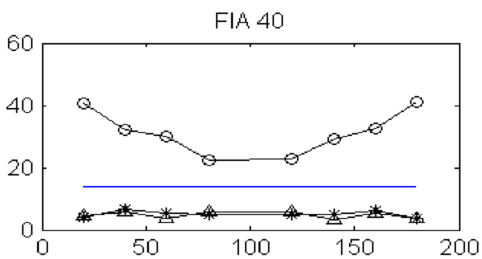
4. RESULTS AND DISCUSSION



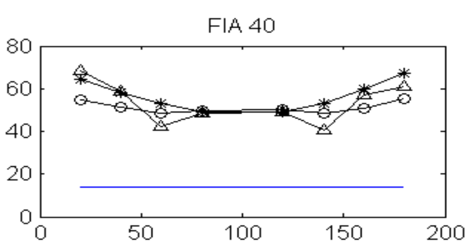
(a)



(b)

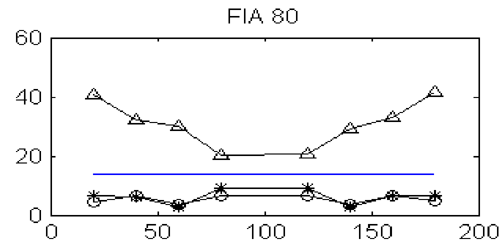


(c)

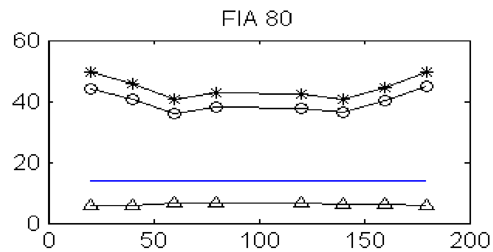


(d)

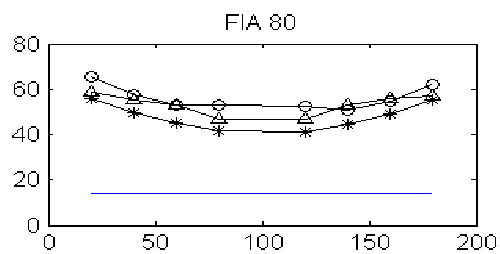
Fig3. Variation of fault index for (a) LG Fault on Phase A (b)LLG Fault on BG (c)LG Fault on Phase C(d) LLLG Fault on Phase ABC



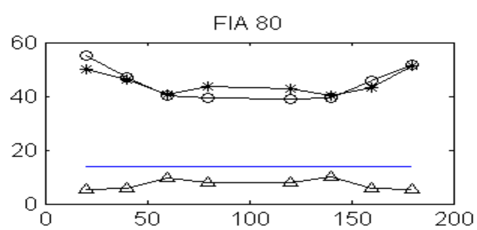
(a)



(b)



(c)



(d)

Fig 4.Variation of fault index

(a) for LG fault on Phase C with STATCOM Controller
(b) for LLG fault on Phase AB with STATCOM Controller
(c) for LLLG fault on Phase ABC with STATCOM Controller
(d) for LL fault on Phase AB with STATCOM Controller

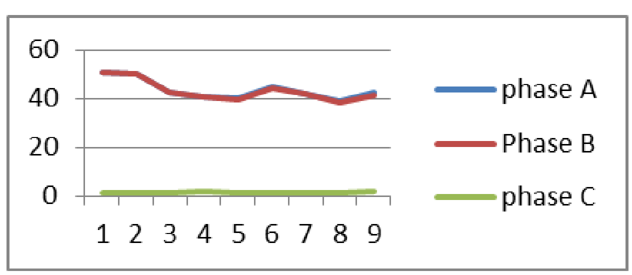


Fig5. LLG Fault without FACTS Controller

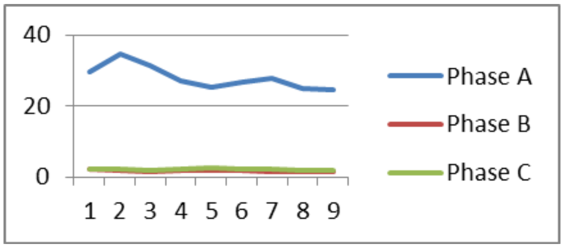


Fig6. LG Fault without FACTS Controller

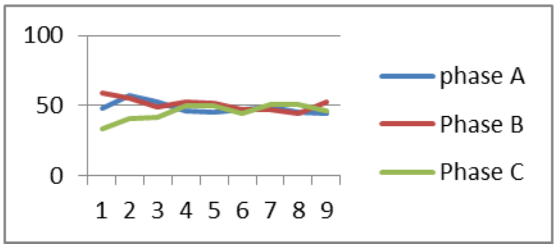


Fig7. LLLG Faults without FACTS Controller

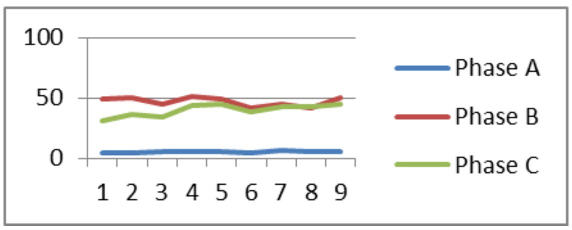


Fig8. LLG Fault with STATCOM Controller

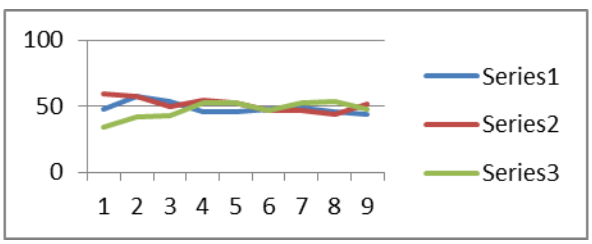


Fig9. LLLG Fault with STATCOM Controller

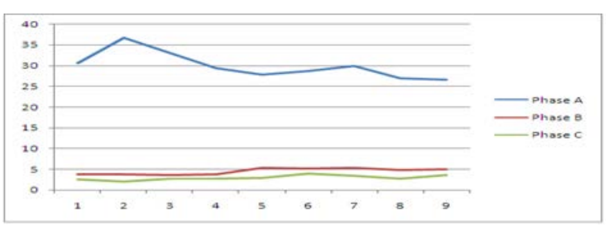


Fig 10.LG Fault with STATCOM Controller

The fault index of three phase currents for transmission line is shown in Figure-3 and the fault index of three phase currents with FACTS controllers are placed at middle of the transmission line shown in Figures 4. It is observed that the fault index of faulty phase is large compared to those of healthy phases. Figure-5 shows the variation of Fault Index I_{f1} incase of ABG fault. Thus the number of faulty phases is determined by comparing the Fault Index (I_{f1}) with a Fault Threshold (T_{f1}). The proposed algorithm has been tested for all types of faults, considering variations in fault locations and fault incidence angles (θ) in the range 0-180^{o}. This scheme is proved to be effective in detecting and classifying various types of faults.

Figures 5, 6&7 show the variation of three phase currents D1 Coefficients of Phase A, Phase B & Phase C for LG, LLG&LLLG fault on transmission line without FACTS Controller. Figure 8,9&10 shows the variation of D1 coefficients for LLG, LLLG and LG fault on transmission line with STATCOM Controller[13][14].

5. CONCLUSION

WT based multi resolution analysis approach can be successfully applied for effective detection and classification of faults in transmission lines. This paper presents an efficient method based on wavelet transforms for fault detection, classification and location which is almost independent of fault impedance, fault distance and fault inception angle of transmission line fault currents with STATCOM controller can be accomplished within a half cycle using detail coefficients of currents at both the ends using ANN technique. The proposed protection scheme is found to be fast, reliable and accurate for various types of faults on transmission lines, at different locations and with variations in incidence angles.

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